5.12

CLOUD LIQUID WATER PATH VARIATION WITH TEMPERATURE DURING SHEBA/FIRE-ACE

Alice Fan[1], Bing Lin[2], Patrick Minnis[2], and Douglas Spangenberg[3]

[1]Science Applications International Corporation, Hampton, VA 23666
[2]NASA Langley Research Center, Hampton, VA 23681
[3]AS&M Inc., Hampton, VA 23666

1. INTRODUCTION

This study evaluates cloud liquid water path (LWP) variations with temperature in polar regions. Del Genio et al. (2000) reported that LWP of mid-latitude low clouds decreases strongly with increasing temperature in summer season due to the reduction in surface relative humility and the increase in the lifting condensation level (LCL). Both factors cause decreases in the cloud physical thickness and ascent of cloud base, and ultimately the decrease of LWP. They did not find obvious cloud top height changes during the thinning. Since the LWP variation with temperature in high-latitudes is not necessarily the same as that in mid-latitudes, investigations for polar region is critical for climate change and cloud feedback studies.

2. DATASETS AND ALGORITHM

This study uses Surface Heat Budget of the Arctic (SHEBA) First International Satellite Cloud Climatology Project Regional Experiment (FIRE) - Arctic Clouds Experiment (ACE) data to analyze polar clouds. SHEBA was undertaken to gain insight on Arctic clouds. This campaign utilized a combination of ship, aircraft, and satellite instruments to accurately and thoroughly measure the desired atmospheric parameters for research and modeling.

2.1 Datasets

SHEBA operation was conducted from October 1997 to September 1998, while cloud amount information derived from AVHRR data of NOAA-12 and 14 satellites is currently only available for FIRE-ACE (May, June, and July 1998). Therefore, this study focuses on these three months. The dual-channel Microwave Radiometer (MWR) that measures radiation at 23.8 GHz and 31.4 GHz is the primary instrument for LWP estimation. In order to obtain the necessary input parameters in retrieving, the following ground-based and satellite data sets were matched with the MWR data to be within 30 minutes: the up-looking IRT measurements (for the estimation of cloud water temperature); satellite cloud amounts, cloud-top temperature, and cloud height (Minnis et al. 2001); surface measurements of air temperature, relative humidity, barometric pressure, and rain-rate; and cloud radar images for identifying single or multiple layer clouds.

2.2 Retrieval Algorithm

The LWP values used in this study are retrieved from ground-based microwave measurements using an algorithm adopted from satellite remote sensing (Lin et al. 2001). This method accounts for the temperature dependence of water absorption and atmospheric gas absorption. Two channels (23.8 GHz and 31.4 GHz) are simultaneously used to retrieve the column-integrated amounts of water vapor and liquid water. The retrieval algorithm needs inputs of air temperature, cloud height, and cloud temperature. The retrieval is an iterative process using the measured brightness temperatures as the target values for microwave radiative transfer simulations.

3. ANALYSIS

During FIRE-ACE, there are only 496 cases found available due to the sparse satellite passes over SHEBA camp site. To analyze the temperature dependence of LWP, only cases with LWP amount between 0.02 mm and 1.0 mm are selected to increase signal-noise-ratio. This exclusion reduces the available cases to 259. Most of them (248) are with cloud cover > 50% (cloudy) and 133 with 100% cloud cover (overcast). Within the cloudy cases, 137 are single layered. Within the overcast cases, 71 are single layered. The correlations between LWP and temperatures are examined for these cases and are listed in table 1. The rows with "M" in the second column means both single and multiple layered clouds, while those with "S" are for single layered clouds only. The numbers in parenthesis are the number of cases. Note that if all retrieved LWP values are used (i.e., the low threshold 0.02 mm is not applied), the analysis still gets similar results as in table 1.

3.1 Cloud temperature vs. LWP

Cloud temperature is significantly positively correlated with LWP. The correlation coefficients are 0.43 and 0.39 for overcast (133) and most cloudy (248) cases. This phenomenon is different from what was observed at mid-latitude regions. The positive correlation is generally true even for all 3-summer-months ground-based MWR LWP data (> 39,000 samples; figure 1).

3.2 Cloud-top height vs. LWP

Cloud-top height is calculated from (surface temperature – cloud-top temperature) / lapse rate. It has a positive correlation with LWP. The correlation coefficients are 0.35 and 0.25 for single layered overcast and most cloudy cases, respectively. This means LWP increases with

---

Corresponding author address: Alice Fan, SAIC, Inc., Hampton, VA 23666; email: t.f.fan@larc.nasa.gov

cloud-top ascents, which is another difference from mid-latitude water clouds. See figure 2 for reference.

3.3 Cloud thickness vs. LWP

As expected, LWP is significantly correlated with cloud thickness (Table 1; Fig. 3). But based on our estimation, the cloud water content has no significant correction with the thickness.

3.4 Cloud thickness vs. cloud temperature

For both single and multiple layered clouds, the cloud thickness increases when cloud (and air) temperature is getting warmer (Table 1, Fig. 4). This suggests that the moisture supply may be a driving factor for cloud formation in polar regions.

Table 1. Correlation coefficients

		Overcast	Cloudy
Cloud temp. vs. LWP	M	0.43 (133)	0.39 (248)
Cloud-top ht vs. LWP	M	0.32 (133)	0.22 (248)
	S	0.35 (73)	0.25 (137)
Cloud thickness vs. LWP	M	0.43 (100)	0.32 (160)
	S	0.54 (48)	0.42 (76)
Cloud thickness vs. Cloud temperature	M	0.57 (100)	0.45 (160)
	S	0.46 (48)	0.33 (76)

4. SUMMARY

The analysis results indicate that LWP and cloud physical thickness increases with cloud warming. The cause of thickening is at least partially due to the ascent of cloud-top height. These phenomena are different from those observed at mid-latitude regions. Further study of the relationship between LWP and cloud temperature should include all four seasons.

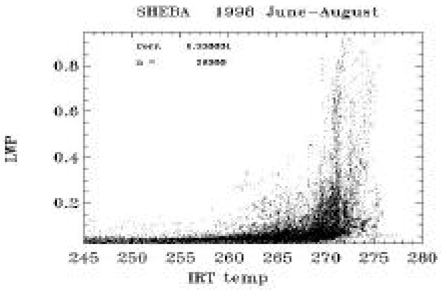

Figure 1

REFERENCES

Del Genio, A. D., Audrey B. Wolf, 2000: The temperature dependence of the liquid water path of low clouds in the Southern Great Plains, J. of Climate, 13, 3465-3486

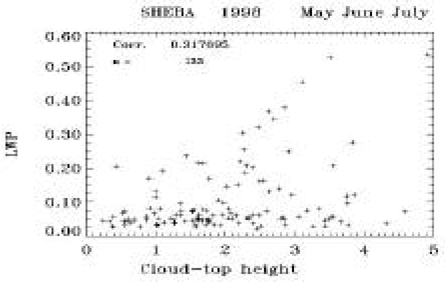

Figure 2

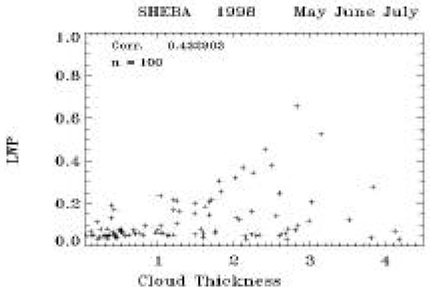

Figure 3

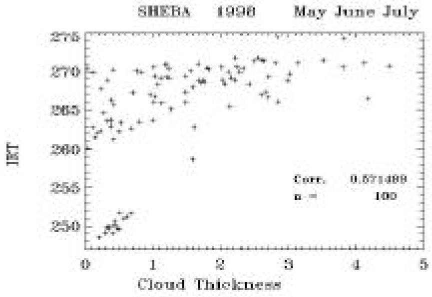

Figure 4

Lin, B., P. Minnis, A. Fan, J. Curry, and H. Gerber, 2001: Comparison of cloud liquid water paths derived from in-situ and microwave radiometer data taken during the SHEBA/FIRE-ACE

Minnis, P., D. Doelling, V. Chakrapani, D.A. Spangenberg, T. Uttal, R. Arduini, M. Shupe, 2001: Cloud coverage and height during FIRE-ACE derived from AVHRR data, J. of Geophys. Res., 106, 15215 –15223